NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 69-FM-199

July 7, 1969

RTCC REQUIREMENTS FOR APOLLO 11 (MISSION G) LUNAR FLYBY MODES OF THE TRANSLUNAR MIDCOURSE CORRECTION PROCESSOR

Lunar Mission Analysis Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

(NASA-TM-X-69742) RTCC REQUIREMENTS FOR APOLLO 11 (MISSION G): LUNAR FLYBY MODES OF THE TRANSLUNAR MIDCOURSE CORRECTION PROCESSOR (NASA) 30 p

N74-71190

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PROJECT APOLLO

RTCC REQUIREMENTS FOR APOLLO 11 (MISSION G): LUNAR FLYBY MODES OF THE TRANSLUNAR MIDCOURSE CORRECTION PROCESSOR

By Kenneth T. Zeiler and Quentin A. Holmes
Lunar Mission Analysis Branch

July 7, 1969

MISSION PLANNING AND ANALYSIS DIVISION
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RTCC REQUIREMENTS FOR APOLLO 11 (MISSION G): LUNAR FLYBY MODES OF THE TRANSLUNAR MIDCOURSE CORRECTION PROCESSOR

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SUMMARY

The supervisor logic for the flyby modes of the Apollo 11 (Mission G) translunar MCC processor for the RTCC contains three distinct options. After an explanation of the underlying trajectory analysis, the use and limitations of each option are briefly discussed.

INTRODUCTION

The translunar midcourse correction processor will be used during translunar coast of Apollo 11 (Mission G) to correct dispersions in the nominal trajectory or, if necessary, to compute alternate lunar missions. The flyby options presented below supersede those set down in the reference (i.e., options 6 and 7).

Circumlunar free-return lunar flybys can be categorized as follows.

(a) Return-to-nominal lunar flyby

(b) Alternate mission lunar flyby following a large dispersion in TLI

(c) Fuel-critical lunar flyby (minimum ΔV) to an unspecified landing

(d) Fuel-critical lunar flyby to a desired longitude at earth landing

The return-to-nominal flyby is already available under the free-return, fixed LPO, BAP option of the midcourse processor. The three flyby options presented in the current work were designed to efficiently compute free-return lunar flybys in categories (b) through (d), respectively, without depending upon preflight data. These options are option 8 - SPS flyby to a specified $INCL_{fr}$ and a desired longitude of earth landing via a specified H_{pl}; option 9A - fully optimum RCS flyby; and option 9B - optimized RCS flyby to a desired inclination of free return. This document contains separate flow diagrams of each of these options and a brief description of their use and limitations.

ABBREVIATIONS

BAP	best adaptive path
H_{pl}	height of perilune
$INCL_{fr}$	inclination of free return
IVTL	inclination of vehicle plane to lunar orbit plane
LOI	lunar orbit insertion
LPO	lunar parking orbit
MCC	midcourse correction maneuver
MED	manual entry device
RCS	reaction control system
RTCC	Real-Time Computer Complex
SPS	service propulsion system
TLI	translunar injection
TLMC	first guess logic for ΔV, $\Delta\gamma$, $\Delta\psi$ of the midcourse maneuver
V	velocity
γ	flight-path angle
Δ	change or difference
ϕ_{pl}	latitude of perilune
ψ	azimuth

METHOD

The vector offset method of simulating integrated trajectories with a conic trajectory computer is common to all three flyby modes. This technique makes possible the optimization of small midcourse maneuvers. It also provides an excellent first guess mechanism for larger maneuvers.

The vector offset method is best described as the missing link between conic and integrated trajectories. Beginning with a state vector in translunar coast, a midcourse maneuver is computed to transfer the spacecraft to a conic circumlunar free-return trajectory. Next an integrated free-return trajectory is computed such that the trajectory passes through the same perilune position as the conic trajectory. The discrepancy between the conic and integrated trajectories is reflected in the difference in their respective midcourse maneuvers (ΔV, $\Delta\gamma$, $\Delta\psi$). An auxiliary state S' is built according to

$$S' = S_2C - \Delta V_I, \Delta\gamma_I, \Delta\psi_I \tag{1}$$

where S_2C is the state after the conic midcourse and ΔV_I, $\Delta\gamma_I$, and $\Delta\psi_I$ are integrated values. When S' is temporarily substituted for the premidcourse state and the integrated midcourse maneuver is applied, then the result will propagate conically to the precision end conditions. This method allows minimization of the integrated maneuver with conic trajectories.

Since the end conditions change, due to optimization, the original bias or offset may be slightly in error. When appropriate, a revised S' may be built using the new end conditions, and the optimization is repeated.

The midcourse maneuver obtained using S' and conic trajectories serves as an excellent first guess for sending the true premidcourse state on an integrated free-return trajectory to the desired end conditions.

OPTION 8 - SPS LUNAR FLYBY TO SPECIFIED $INCL_{fr}$ AND A DESIRED LONGITUDE OF EARTH LANDING

Option 8 (flow chart 1) will normally be called when TLI cutoff is so far from nominal that the required ΔV_{mcc} precludes a lunar orbit mission. This option does not involve optimization.

The longitude at earth landing depends upon the total mission time free return, which in turn is determined by the altitude at perilune. A 100-n. mi. increase in perilune altitude increases the total mission time by about 2 hours and moves the longitude of earth landing westward by approximately 33°. The specified inclination of free return may be any value greater than the declination of the moon (at the time of perilune passage) plus 5°. A distinction is made between ascending and descending returns.

Applicability of option 8 is limited solely by the ΔV capability of the SPS. However, for large dispersions ΔV_{mcc} increases rapidly with delay times. Thus, for large maneuvers this option will be exercised early in the translunar coast.

The detailed flow of the computational steps in option 8 is given in flow chart 1. Beginning with an initial state vector in translunar coast phase, conic TLMC (step 1) is used to provide first guesses for computation of a conic flyby (step 2) to obtain the perilune latitude (ϕ_{split}) associated with the lowest possible inclination of free return.

In step 3, a conic trajectory is converged to a latitude of perilune either 2° north or 2° south of ϕ_{split} depending on whether an ascending or descending inclination of return has been specified. An integrated free return (step 4) is then converged with the same latitude and height of perilune as step 3. Following this, another integrated free return (step 5) is converged with the inclination of return and height of perilune identical to step 3. When step 5 is complete, the postmidcourse state vector (S_2C) of step 3 and the midcourse components of step 5 are used to compute the offset state vector according to the equation

$$S' = S_2C - \Delta\dot{X}_I, \Delta\dot{Y}_I, \Delta\dot{Z}_I$$

First guesses are computed for step 6 as follows.

$$S_2C \text{ (polarform)} - S' \text{ (polarform)} = \Delta V, \Delta\gamma, \Delta\psi$$

Step 6 is a conic free return that converges with the desired inclination of return and height of perilune using the premidcourse state vector S'. This step is not optimized. Step 7 uses the original premidcourse state vector and converges with the same conditions as the previous step. This final step produces the precision midcourse maneuver for the specified free-return trajectory conditions.

Steps 1 through 6 are used to provide first guesses for the final step and to insure that a distinction is made between ascending and descending returns. The results are excellent. Rarely are more than two iterations required for step 7 to converge. The total run time of this scheme is about 50 percent of that required if integrated TLMC is used to provide first guesses directly to step 7.

OPTION 9A - FUEL CRITICAL LUNAR FLYBY

This option (flow chart 2) will determine the cheapest possible (least ΔV) lunar flyby. The only direct trajectory constraints are the inclination of free return, which must be less than 90°, and the minimum and maximum allowable heights of perilune, which are 60 n. mi. and 2000 n. mi., respectively, unless overridden by a MED.

Step 1 computes a conic free-return trajectory which converges with a perilune height of 80 n. mi. (subject to MED) and an inclination of free return which is 2° greater than the declination of the moon. The latitude of perilune (ϕ_{split}) obtained from this step is used to separate ascending and descending inclinations of return. Step 2 converges a conic trajectory to a latitude of perilune 2° south of ϕ_{split}. This is followed by an integrated trajectory with the same specifications (step 3). In step 4, an integrated trajectory is converged with the same inclination of return as step 2, Next, the offset vector S' is computed with the same method used in option 8.

The premidcourse state vector S' is used in steps 5, 6, and 7. Step 5 selects a conic trajectory with an inclination of return of -85° and a perilune height between 60 n. mi. and 2000 n. mi. Step 6 optimizes the midcourse maneuver with the inclination of return still fixed at -85°. In step 7, the inclination is released to permit complete optimization.

Step 8 uses the original premidcourse state vector S_1 and converges an integrated trajectory with the optimum height and inclination of step 7. If the ΔV_{mcc} of step 8 differs with that of step 7 by more than 1 fps or 3 percent, a new S' vector will be computed and steps 7 and 8 will be repeated to obtain the prescribed ΔV agreement.

Having completed a scan of the descending inclinations, the program now returns to step 2 and begins a similar search of the ascending inclinations. Step 2 converges a conic trajectory to a latitude of perilune 2° north of ϕ_{split}. This step uses the S' state vector previously computed with steps 2, 3, and 4. Since the program already has the necessary S' vector, steps 3 and 4 are skipped. The above procedure involving steps 5, 6, 7, and 8 is now repeated, with steps 5 and 6 targeted to an inclination of return of +85°. When optimization is completed, the ΔV_{mcc} of the respective integrated trajectories is compared and the cheapest maneuver is chosen as the solution.

It should be noted that the earth landing point obtained from this option depends upon the dispersion involved and usually bears little relation to the nominal impact point.

OPTION 9B - OPTIMIZED RCS FLYBY TO A DESIRED INCLINATION OF FREE RETURN

This option will normally be used to compute small midcourse corrections if the SPS fails and the fully optimum RCS flyby yields a ΔV_{mcc} which is well within the RCS capability. This option can be exercised during translunar coast from TLI cutoff plus 3 hours to LOI minus 2 hours. It can also be used for larger maneuvers should the nominal free-return impact point be undesirable.

Flow chart 3 gives the detailed flow of option 9B. The first five steps of option 9B are identical to those of option 8. Using the S' state vector computed with steps 2, 3, and 4, step 6 converges a conic trajectory with the specified inclination of return and a height of perilune that is 20 n. mi. greater than the minimum input value. The standard range of perilune altitude is 60 n. mi. to 2000 n. mi., but these values are subject to MED input. In step 7, the height of perilune is opened up, and the conic trajectory is optimized within the specified limits. Using the original premidcourse vector, step 8 converges on integrated trajectory with the specified free-return inclination and the optimum perilune height.

If the ΔV_{mcc} of step 8 differs with that of step 7 by more than 1 fps or 3 percent, a new S' vector is computed and steps 7 and 8 are repeated. When the ΔV agreement is satisfactory, the program exits.

This option permits the user to compute optimum flybys that return to a desired earth longitude by ranging the limits of perilune altitude or the inclination of return or both. Given an inclination of return, variations in the height of perilune will result in a range of landing longitudes with a corresponding range in midcourse ΔV. With a different inclination of return, the same range of earth longitudes is available for a substantially different cost in ΔV. The relationship between height of perilune, inclination of return, and midcourse ΔV presents several solutions to one problem, some of which are better than others. Repeated use of this option permits a tradeoff to be made between the variables mentioned.

ENTER WITH STATE VECTOR AND DELAY TIME TO MCC

STEP 1

COMPUTE MCC FIRST GUESSES WITH CONIC TLMC

STEP 2

EXECUTE CONIC FLYBY TO OBTAIN PERILUNE LATITUDE OF MINIMUM $INCL_{FR}$ FLYBY

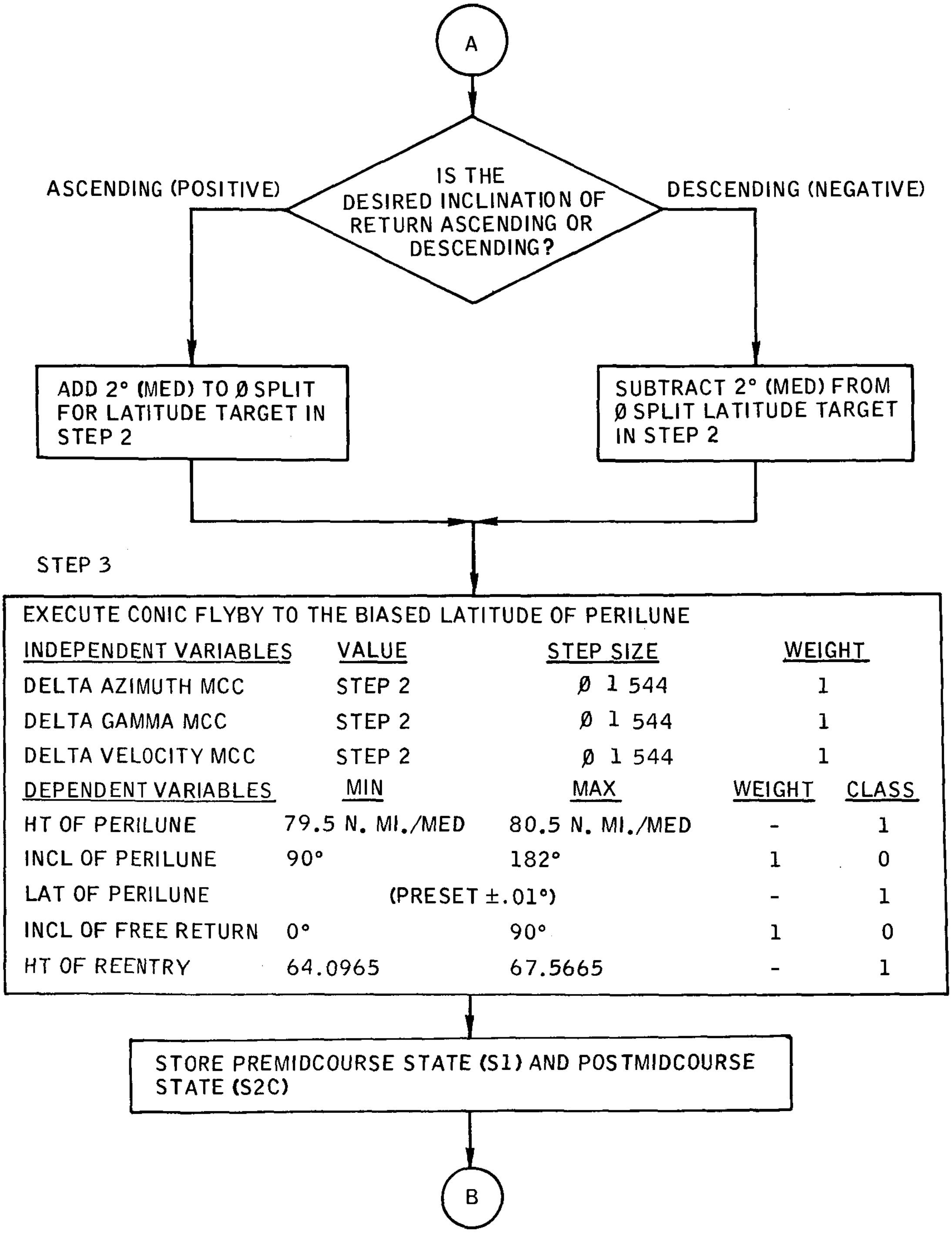
INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT	
DELTA AZIMUTH MCC	CONIC TLMC	Ø 1 544	1	
DELTA GAMMA MCC	CONIC TLMC	Ø 1 544	1	
DELTA VELOCITY MCC	CONIC TLMC	Ø 1 524	1	
DEPENDENT VARIABLES	**MIN**	**MAX**	**WEIGHT**	**CLASS DESIGNATOR**
HT OF PERILUNE	79.5 N. MI./MED	80.5 N. MI./MED	-	1
INCL OF PERILUNE	90°	182°	1	0
HT OF REENTRY	64.0965	67.5665	-	1
INCL OF FREE RETURN	-.01° ($DECL_{MOON}$ +2°) *	+.01°	-	1

*AT THE EXPECTED TIME OF PERILUNE PASSAGE

STORE LATITUDE OF PERILUNE ($Ø_{SPLIT}$) OBTAINED IN STEP 2

A

FLOW CHART 1.- SPS LUNAR FLYBY.



FLOW CHART 1.-SPS LUNAR FLYBY-CONTINUED.

B

COMPUTE MCC FIRST GUESSES WITH INTEGRATED TLMC USING LATITUDE OF PERILUNE FROM STEP 3

STEP 4

EXECUTE INTEGRATED FLYBY TO THE SAME LATITUDE OF PERILUNE AS STEP 3

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT
DELTA AZIMUTH MCC	INTEGRATED TLMC	Ø 1 544	1
DELTA GAMMA MCC	INTEGRATED TLMC	Ø 1 544	1
DELTA VELOCITY MCC	INTEGRATED TLMC	Ø 1 524	1

DEPENDENT VARIABLES	MIN	MAX	WEIGHT	CLASS
HT OF PERILUNE	79.5 N. MI./MED	80.5 N. MI./MED	-	1
INCL OF PERILUNE	90°	182°	1	0
LAT OF PERILUNE	(SAME AS STEP 3)		-	1
INCL OF FREE RETURN	0°	90°	1	0
HT OF REENTRY	64.0965	67.5665	-	1

STEP 5

EXECUTE INTEGRATED FLYBY TO SAME INCL OF FREE RETURN AND HEIGHT AS STEP 2

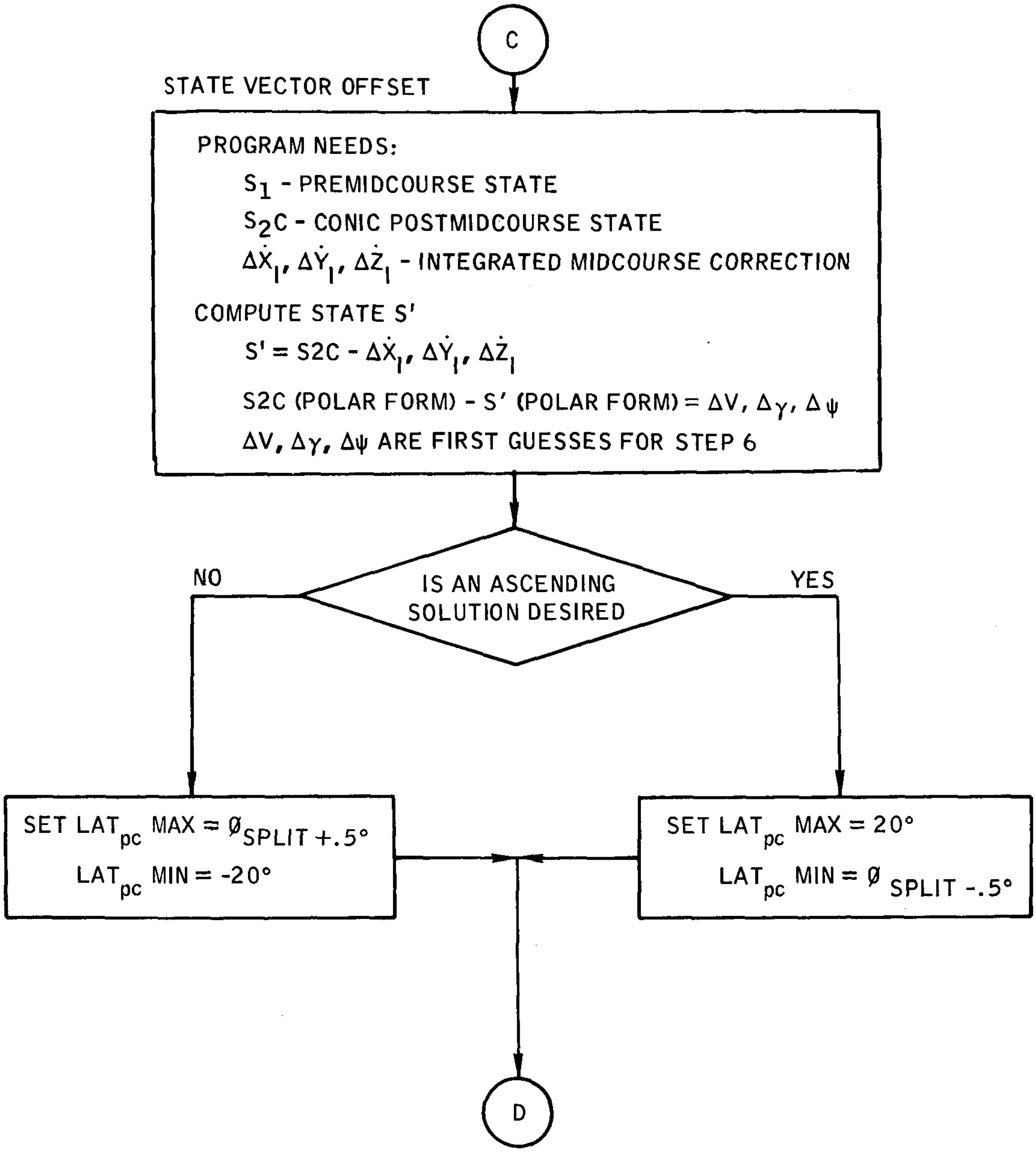
INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT
DELTA AZIMUTH MCC	STEP 4	Ø 1 544	1
DELTA GAMMA MCC	STEP 4	Ø 1 544	1
DELTA VELOCITY MCC	STEP 4	Ø 1 524	1

DEPENDENT VARIABLES	MIN	MAX	WEIGHT	CLASS
HT OF PERILUNE	79.5 N. MI./MED	80.5 N. MI./MED	-	1
INCL OF PERILUNE	90°	182°	1	0
INCL OF FREE RETURN	(CONV VALUE FROM STEP 3 ± .01°)		-	1
HT OF REENTRY	64.0965	67.5665	-	1

STORE INTERGRATED MANEUVER ($\Delta\dot{X}_I$, $\Delta\dot{Y}_I$, $\Delta\dot{Z}_I$)

C

FLOW CHART 1.- SPS LUNAR FLYBY - CONTINUED.



FLOW CHART 1.- SPS LUNAR FLYBY - CONTINUED.

D

STEP 6

CONVERGE A CONIC FREE RETURN (SELECT MODE USING S' AS THE STATE VECTOR)

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT
DELTA AZIMUTH MCC	COMPUTED	Ø 1 544	1
DELTA GAMMA MCC	COMPUTED	Ø 1 544	1
DELTA VELOCITY MCC	COMPUTED	Ø 1 524	1

DEPENDENT VARIABLES	MIN	MAX	WEIGHT	CLASS DESIGNATOR
HT OF PERILUNE	-.5 N. MI. MED	+.5 N. MI.	-	1
INCL OF PERILUNE	90°	182°	1	0
LAT OF PERILUNE	PRESET	PRESET	32	0
INCL OF FREE RETURN	-.01° MED	+.01° MED	-	1
HT OF REENTRY	64.0965 N. MI.	67.5665	-	1

E

FLOW CHART 1.- SPS LUNAR FLYBY - CONTINUED.

E

RESTORE THE ORIGINAL PREMIDCOURSE STATE (S1) AND COMPUTE FIRST GUESSES FOR STEP 7 USING THE LATEST S2C:

$S2C - S' = \Delta\dot{X}, \Delta\dot{Y}, \Delta\dot{Z}$

$(S1 + \Delta\dot{X}, \Delta\dot{Y}, \Delta\dot{Z})_{POLAR\ FORM} - S1_{POLAR\ FORM} =$

$\Delta V, \Delta_{\gamma}, \Delta_{\psi}$

STEP 7

CONVERGE INTEGRATED FLYBY TO SPECIFIED INCL OF FREE RETURN AND HEIGHT USING STATE S1

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT
DELTA AZIMUTH MCC	COMPUTED	Ø 1 544	1
DELTA GAMMA MCC	COMPUTED	Ø 1 544	1
DELTA VELOCITY MCC	COMPUTED	Ø 1 524	1

DEPENDENT VARIABLES	MIN	MAX	WEIGHT	CLASS
HT OF PERILUNE	-.5 N. MI.	STEP 6 + .5 N. MI.	-	1
INCL OF FREE RETURN	MED -.01°	MED +.01°	-	1
INCL OF PERILUNE	90°	182°	1	0
HT OF REENTRY	64.0965 N. MI.	67.5665 N. MI.	-	1

EXIT

FLOW CHART 1.- SPS LUNAR FLYBY - CONCLUDED.

ENTER WITH STATE VECTOR AND DELAY TIME TO MCC

COMPUTE MCC FIRST GUESSES WITH CONIC TLMC

STEP 1

EXECUTE CONIC FLYBY TO OBTAIN PERILUNE LATITUDE OF MINIMUM $INCL_{fr}$ FLYBY

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT
DELTA AZIMUTH MCC	CONIC TLMC	Ø 1 544	1
DELTA GAMMA MCC	CONIC TLMC	Ø 1 544	1
DELTA VELOCITY MCC	CONIC TLMC	Ø 1 524	1

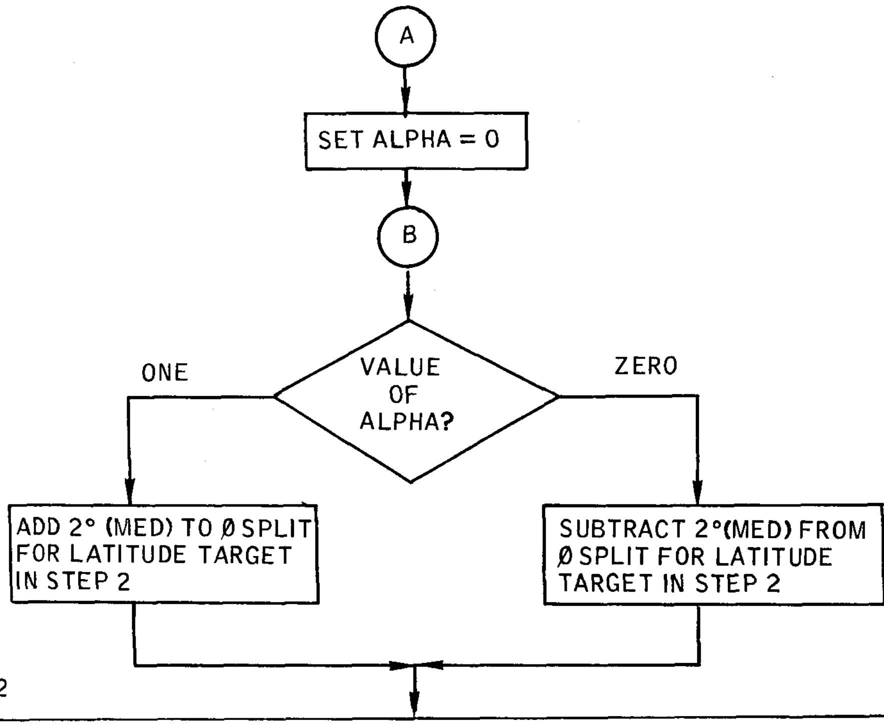
DEPENDENT VARIABLES	MIN	MAX	WEIGHT	CLASS DESIGNATOR
HT OF PERILUNE	79.5 N. MI./MED	80.5 N. MI./MED	-	1
INCL OF PERILUNE	90°	182°	1	0
HT OF REENTRY	64.0965	67.5665	-	1
INCL OF FREE RET	-.01° ($DECL_{MOON}$	+2°) +.01°*	-	1

*AT THE EXPECTED TIME OF PERILUNE PASSAGE

STORE LATITUDE OF PERILUNE ($Ø_{SPLIT}$) OBTAINED IN STEP 2

A

FLOW CHART 2.- OPTIMIZED LUNAR FLYBY.

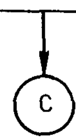


STEP 2

EXECUTE CONIC FLYBY TO THE BIASED LATITUDE OF PERILUNE

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT
DELTA AZIMUTH MCC	STEP 1	Ø 1 544	1
DELTA GAMMA MCC	STEP 1	Ø 1 544	1
DELTA VELOCITY MCC	STEP 1	Ø 1 544	1

DEPENDENT VARIABLES	MIN	MAX	WEIGHT	CLASS
HT OF PERILUNE	79.5 N. MI./MED	80.5 N. MI./MED	-	1
INCL OF PERILUNE	90°	182°	1	0
LAT OF PERILUNE	(PRESET ± .01°)		-	1
INCL OF FREE RETURN	0°	90°	1	0
HT OF REENTRY	64.0965	67.5665	-	1



FLOW CHART 2.- OPTIMIZED LUNAR FLYBY (CONTINUED).

C

VALUE OF ALPHA?

ONE → E

ZERO

STORE PREMIDCOURSE STATE (S1) AND POSTMIDCOURSE STATE (S2C)

COMPUTE MCC FIRST GUESSES WITH INTEGRATED TLMC USING LATITUDE OF PERILUNE FROM STEP 2

STEP 3

EXECUTE INTEGRATED FLYBY TO THE SAME LATITUDE OF PERILUNE AS STEP 2

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT
DELTA AZIMUTH MCC	INTEGRATED TLMC	Ø 1 544	1
DELTA GAMMA MCC	INTEGRATED TLMC	Ø 1 544	1
DELTA VELOCITY MCC	INTEGRATED TLMC	Ø 1 524	1

DEPENDENT VARIABLES	MIN	MAX	WEIGHT	CLASS
HT OF PERILUNE	79.5 N. MI./MED	80.5 N. MI./MED	-	1
INCL OF PERILUNE	90°	182°	1	0
LAT OF PERILUNE	(PRESET ± .01°)		-	1
INCL OF FREE RETURN	0°	90°	1	0
HT OF REENTRY	64.0965	67.5665	-	1

STEP 4

EXECUTE INTEGRATED FLYBY TO SAME INCL OF FREE RETURN AND HEIGHT AS STEP 2

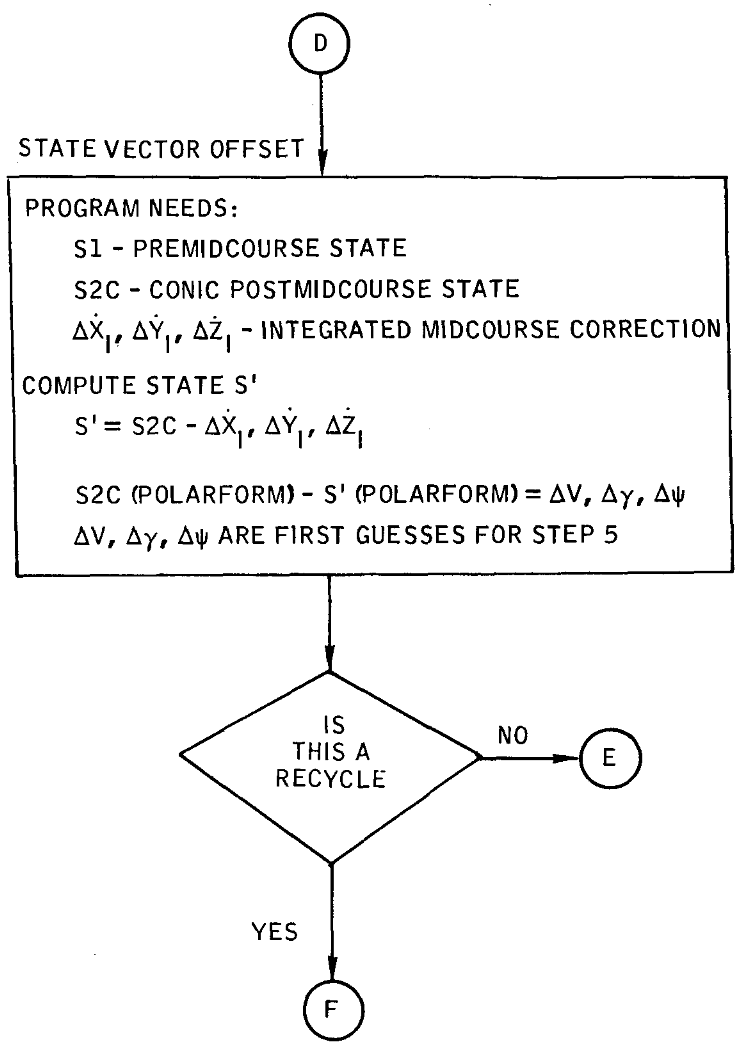
INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT
DELTA AZIMUTH MCC	STEP 3	Ø1 544	1
DELTA GAMMA MCC	STEP 3	Ø1 544	1
DELTA VELOCITY MCC	STEP 3	Ø1 524	1

DEPENDENT VARIABLES	MIN	MAX	WEIGHT	CLASS
HT OF PERILUNE	79.5 N. MI./MED	80.5 N. MI./MED	-	1
INCL OF PERILUNE	90°	182°	1	0
INCL OF FREE RETURN	(CONV VALUE FROM STEP 2 ± .01°)		1	0
HT OF REENTRY	64.0965	67.5665	-	1

STORE INTEGRATED MANEUVER $(\Delta\dot{X}_I, \Delta\dot{Y}_I, \Delta\dot{Z}_I)$

D

FLOW CHART 2.- OPTIMIZED LUNAR FLYBY (CONTINUED).



FLOW CHART 2.- OPTIMIZED LUNAR FLYBY (CONTINUED).

E

VALUE OF ALPHA ?

ONE

SET LAT_{pc} MAX = 20°

LAT_{pc} MIN = Ø SPLIT -.5°

ZERO

SET LAT_{pc} MAX = Ø SPLIT + .5°

LAT_{pc} MIN = -20°

USE THE S' STATE COMPUTED WITH STEPS 2 AND 4 FOR THE FOLLOWING STEP

STEP 5

CONVERGE A CONIC FREE RETURN (SELECT MODE USING S' AS THE STATE VECTOR)

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT	
DELTA AZIMUTH MCC	COMPUTED	Ø 1 544	1	
DELTA GAMMA MCC	COMPUTED	Ø 1 544	1	
DELTA VELOCITY MCC	COMPUTED	Ø 1 524	1	
DEPENDENT VARIABLES	**MIN**	**MAX**	**WEIGHT**	**CLASS DESIG**
HT OF PERILUNE	60 N. MI./MED	2 000 N. MI./MED	8	0
INCL OF PERILUNE	90°	180°	1	0
LAT OF PERILUNE	PRESET	PRESET	32	0
INCL OF FREE RET	84.5°	85.5°	-	1
HT OF REENTRY	64.0965 N. MI.	67.5665 N. MI.	-	1

DID CASE CONVERGE

NO → EXIT

YES

STEP 6

MAXIMIZE MASS AFTER MIDCOURSE HOLDING INCL FREE RET CONSTANT

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT	
DELTA AZIMUTH MCC	PREVIOUS STEP	Ø 1 544	1	
DELTA GAMMA MCC	PREVIOUS STEP	Ø 1 544	1	
DELTA VELOCITY MCC	PREVIOUS STEP	Ø 1 524	1	
DEPENDENT VARIABLES	**MIN**	**MAX**	**WEIGHT**	**CLASS DESIG**
HT OF PERILUNE	60 N. MI./MED	2 000 N. MI./MED	8	0
INCL OF PERILUNE	90°	182°	1	0
INCL OF FREE RET	84.9	85.1	-	1
HT OF REENTRY	63.8315 N. MI.	67.8315 N. MI.	-	1
MASS AFTER MIDCOURSE	PICK UP MASS + 5 000 LBS		X8*	-1

YES

F

STEP 7

USING CONIC TRAJECTORIES OPTIMIZE MASS AFTER MCC USING S' AS THE STATE VECTOR

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT	
DELTA AZIMUTH MCC	PREVIOUS STEP	Ø 1 544	1	
DELTA GAMMA MCC	PREVIOUS STEP	Ø 1 544	1	
DELTA VELOCITY MCC	PREVIOUS STEP	Ø 1 524	1	
DEPENDENT VARIABLES	**MIN**	**MAX**	**WEIGHT**	**CLASS DESIG**
HT OF PERILUNE	60 N. MI./MED	2 000 N. MI./MED	8	0
INCL OF PERILUNE	90°	182°	1	0
INCL OF FREE RET	0	88°	1	0
HT OF REENTRY	63.8315 N. MI.	67.8315 N. MI.	-	1
MASS AFTER MCC	PICK UP MASS + 5 000 LBS		X8*	-1

H

* INHOUSE VERSION USES 128 AS A MULTIPLIER

FLOW CHART 2.- OPTIMIZED LUNAR FLYBY (CONTINUED).

H

STORE NEW POSTMIDCOURSE STATE S2C

RESTORE THE ORIGINAL PREMIDCOURSE STATE VECTOR (S1) AND COMPUTE FIRST GUESSES FOR STEP 8 USING THE LATEST S2C:

$S2C - S' = \Delta\dot{X}, \Delta\dot{Y}, \Delta\dot{Z}$

$(S1 + \Delta\dot{X}, \Delta\dot{Y}, \Delta\dot{Z})$ POLAR FORM $- S1 = \Delta V, \Delta\gamma, \Delta\psi$

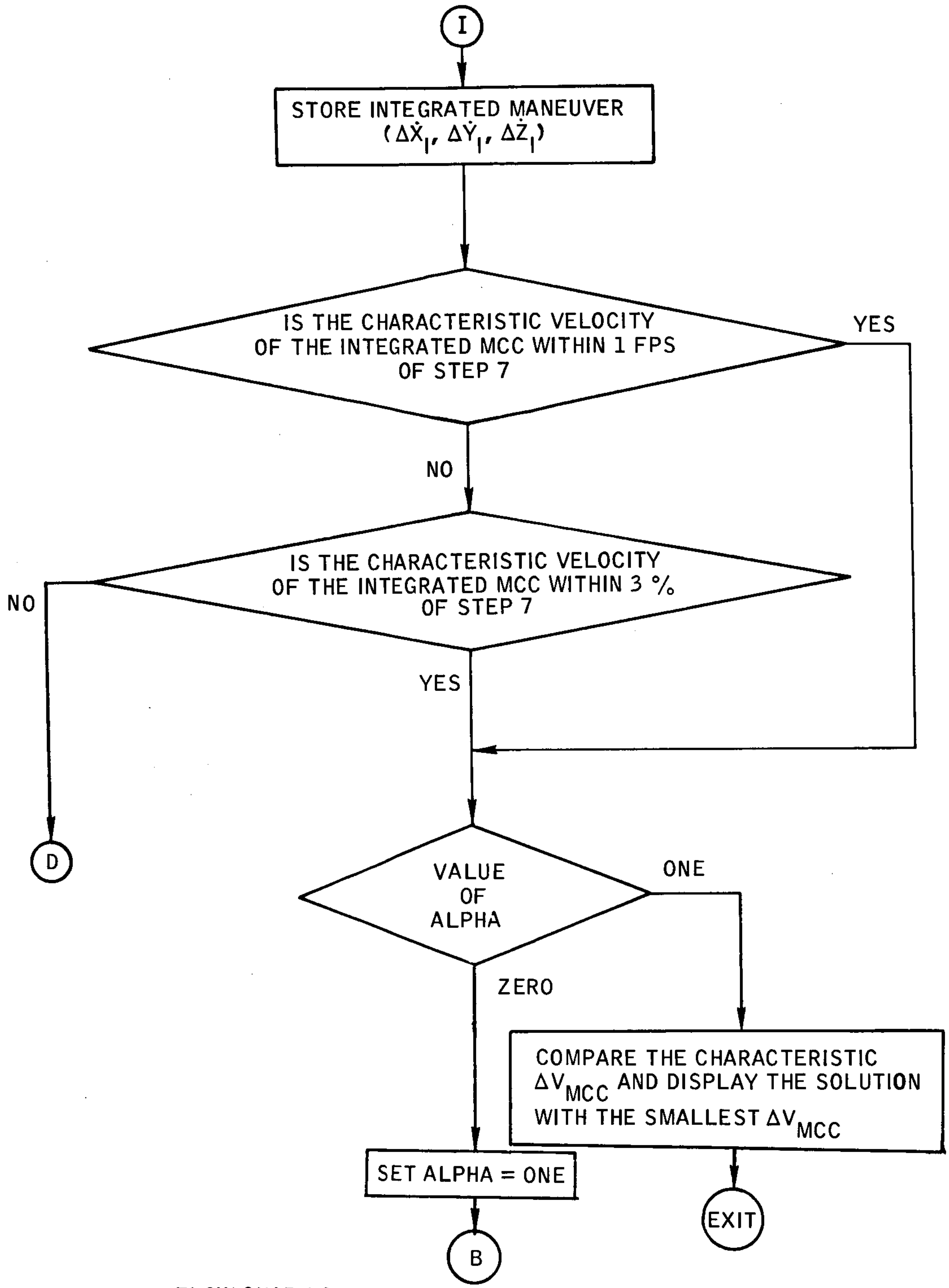
STEP 8

CONVERGE INTEGRATED FLYBY TO OPTIMUM INCL OF FREE RETURN AND HEIGHT USING STATE S1

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT	
DELTA AZIMUTH MCC	COMPUTED	Ø 1 544	1	
DELTA GAMMA MCC	COMPUTED	Ø 1 544	1	
DELTA VELOCITY MCC	COMPUTED	Ø 1 524	1	
DEPENDENT VARIABLES	**MIN**	**MAX**	**WEIGHT**	**CLASS**
HT OF PERILUNE	-.5 N. MI. OPT	+.5 N. MI. OPT	-	1
INCL OF FREE RETURN	-.01° OPT	+.01° OPT	-	1
INCL OF PERILUNE	90°	182°	1	0
HT OF REENTRY	64.0965 N. MI.	67.5665 N. MI.	-	1

I

FLOW CHART 2.- OPTIMIZED LUNAR FLYBY (CONTINUED).



FLOW CHART 2.- OPTIMIZED LUNAR FLYBY (CONTINUED).

ENTER WITH STATE VECTOR AND DELAY TIME TO MCC

STEP 1

COMPUTE MCC FIRST GUESSES WITH CONIC TLMC

STEP 2

EXECUTE CONIC FLYBY TO OBTAIN PERILUNE LATITUDE OF MINIMUM $INCL_{FR}$ FLYBY

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT
DELTA AZIMUTH MCC	CONIC TLMC	Ø 1 544	1
DELTA GAMMA MCC	CONIC TLMC	Ø 1 544	1
DELTA VELOCITY MCC	CONIC TLMC	Ø 1 524	1

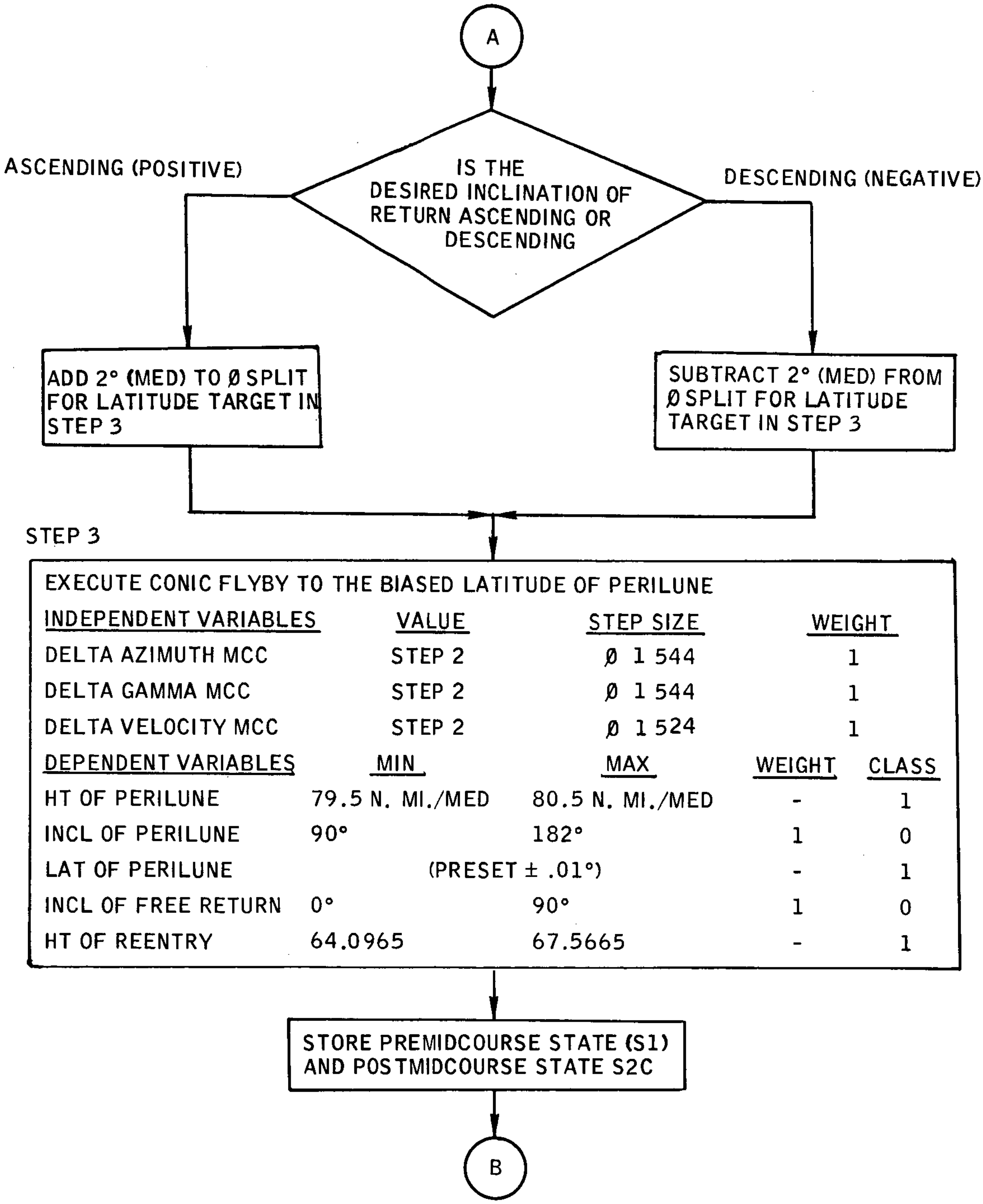
DEPENDENT VARIABLES	MIN	MAX	WEIGHT	CLASS DESIG
HT OF PERILUNE	79.5 N. MI./MED	80.5 N. MI./MED	-	1
INCL OF PERILUNE	90°	182°	1	0
HT OF REENTRY	64.0965	67.5665	-	1
INCL OF FREE RETURN	-.01°	$(DECL_{MOON}+2°)$ * +.01°	-	1

*AT THE EXPECTED TIME OF PERILUNE PASSAGE

STORE LATITUDE OF PERILUNE ($Ø_{SPLIT}$) OBTAINED IN STEP 2

A

FLOW CHART 3.- OPTIMIZED RCS FLYBY TO A DESIRED INCLINATION OF FREE RETURN.



INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT	
DELTA AZIMUTH MCC	STEP 2	Ø 1 544	1	
DELTA GAMMA MCC	STEP 2	Ø 1 544	1	
DELTA VELOCITY MCC	STEP 2	Ø 1 524	1	
DEPENDENT VARIABLES	**MIN**	**MAX**	**WEIGHT**	**CLASS**
HT OF PERILUNE	79.5 N. MI./MED	80.5 N. MI./MED	-	1
INCL OF PERILUNE	90°	182°	1	0
LAT OF PERILUNE	(PRESET ± .01°)		-	1
INCL OF FREE RETURN	0°	90°	1	0
HT OF REENTRY	64.0965	67.5665	-	1

FLOW CHART 3.- OPTIMIZED RCS FLYBY TO A DESIRED INCLINATION OF FREE RETURN (CONTINUED).

B

COMPUTE MCC FIRST GUESSES WITH INTEGRATED TLMC USING LATITUDE OF PERILUNE FROM STEP 3

STEP 4

EXECUTE INTEGRATED FLYBY TO THE SAME LATITUDE OF PERILUNE AS STEP 3

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT	
DELTA AZIMUTH MCC	INTEGRATED TLMC	Ø 1 544	1	
DELTA GAMMA MCC	INTEGRATED TLMC	Ø 1 544	1	
DELTA VELOCITY MCC	INTEGRATED TLMC	Ø 1 524	1	
DEPENDENT VARIABLES	**MIN**	**MAX**	**WEIGHT**	**CLASS**
HT OF PERILUNE	79.5 N. MI./MED	80.5 N. MI./MED	-	1
INCL OF PERILUNE	90°	182°	1	0
LAT OF PERILUNE	(PRESET ± .01°)		-	1
INCL OF FREE RETURN	0°	90°	1	0
HT OF REENTRY	64.0965	67.5665	-	1

STEP 5

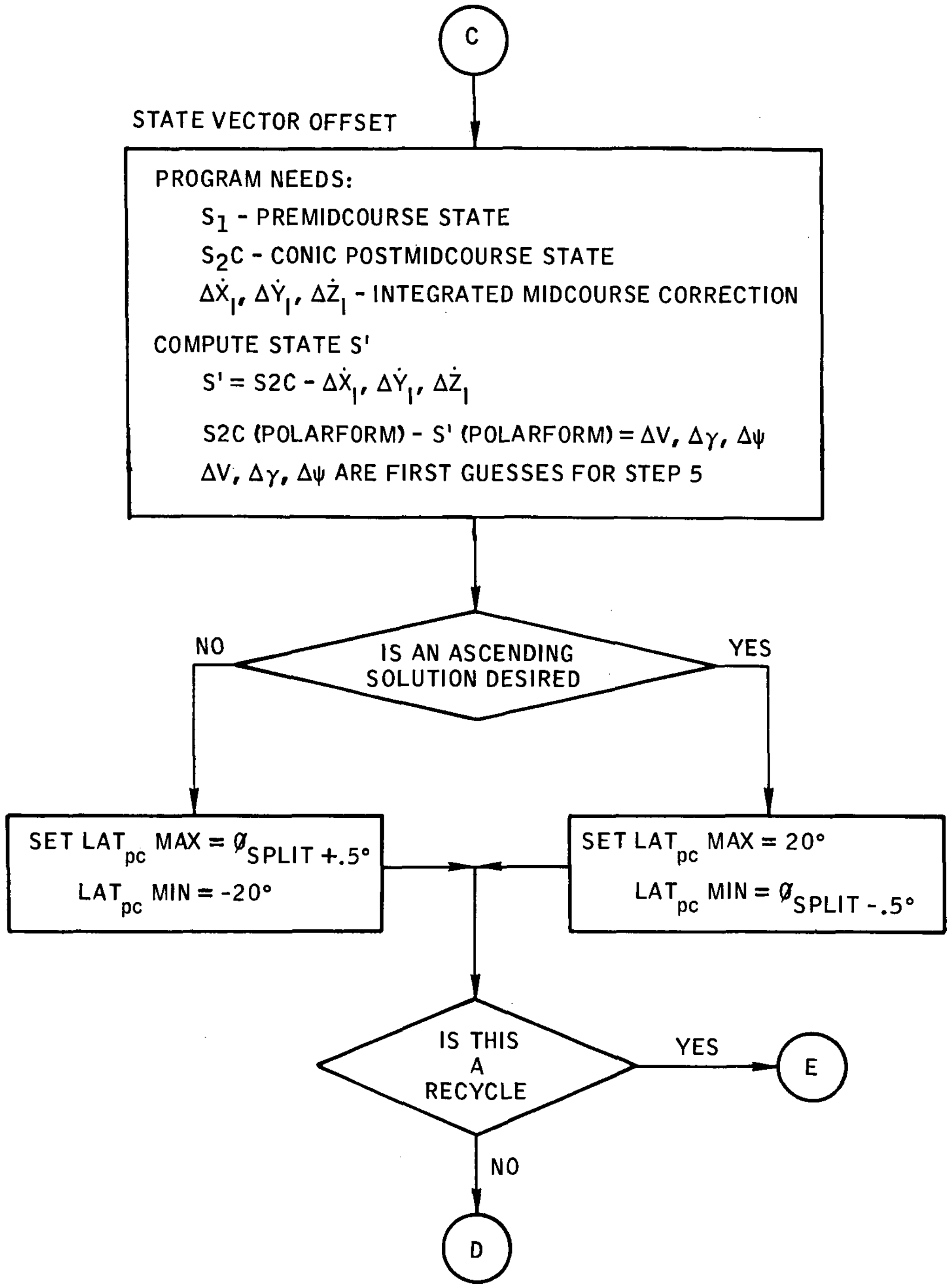
EXECUTE INTEGRATED FLYBY TO SAME INCL OF FREE RETURN AND HEIGHT AS STEP 2

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT	
DELTA AZIMUTH MCC	STEP 4	Ø 1 544	1	
DELTA GAMMA MCC	STEP 4	Ø 1 544	1	
DELTA VELOCITY MCC	STEP 4	Ø 1 524	1	
DEPENDENT VARIABLES	**MIN**	**MAX**	**WEIGHT**	**CLASS**
HT OF PERILUNE	79.5 N. MI./MED	80.5 N. MI./MED	-	1
INCL OF PERILUNE	90°	182°	1	0
INCL OF FREE RETURN	(CONV VALUE FROM STEP 3 ± .01°)		-	1
HT OF REENTRY	64.0965	67.5665	-	1

STORE INTEGRATED MANEUVER ($\Delta\dot{X}_I$, $\Delta\dot{Y}_I$, $\Delta\dot{Z}_I$)

C

FLOW CHART 3.- OPTIMIZED RCS FLYBY TO A DESIRED INCLINATION OF FREE RETURN (CONTINUED).



FLOW CHART 3.- OPTIMIZED RCS FLYBY TO A DESIRED INCLINATION OF FREE RETURN (CONTINUED).

D

STEP 6

CONVERGE A CONIC FREE RETURN (SELECT MODE USING S' AS THE STATE VECTOR)

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT
DELTA AZIMUTH MCC	$\Delta\psi_I$	Ø 1 544	1
DELTA GAMMA MCC	$\Delta\gamma_I$	Ø 1 544	1
DELTA VELOCITY MCC	ΔV_I	Ø 1 524	1

DEPENDENT VARIABLES	MIN		MAX	WEIGHT	CLASS DESIG
HT OF PERILUNE	-.5 N. MI.	{MIN OF STEP 7 + 20 N. MI.}	+.5 N. MI.	-	1
INCL OF PERILUNE	90°		182°	1	0
LAT OF PERILUNE	PRESET		PRESET	32	0
INCL OF FREE RETURN	+.01° MED		-.01° MED	-	1
HT OF REENTRY	64.0965 N. MI.		67.5665	-	1

DID CASE CONVERGE

NO → EXIT

STEP 7

E → YES

USING CONIC TRAJECTORIES OPTIMIZE MASS AFTER MCC USING S' AS THE STATE VECTOR

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT
DELTA AZIMUTH MCC	STEP 6/$\Delta\psi_I$	Ø 1 544	1
DELTA GAMMA MCC	STEP 6/$\Delta\gamma_I$	Ø 1 544	1
DELTA VELOCITY MCC	STEP 6/ΔV_I	Ø 1 524	1

DEPENDENT VARIABLES	MIN	MAX	WEIGHT	CLASS DESIG
HT OF PERILUNE	60 N. MI./MED	2000 N. MI./MED	8	0
INCL OF PERILUNE	90°	182°	1	0
LAT OF PERILUNE	PRESET	PRESET	32	0
INCL OF FREE RETURN	-0.1° MED	+0.1° MED	-	1
HT OF REENTRY	63.8315 N. MI.	67.8315 N. MI.	-	1
MASS AFTER MCC	PICKUP MASS + 5 000 LBS		X8*	-1

* IN HOUSE VERSION USES 128 AS A MULTIPLIER

F

FLOW CHART 3.- OPTIMIZED RCS FLYBY TO A DESIRED INCLINATION OF FREE RETURN (CONTINUED).

F

STORE NEW POSTMIDCOURSE STATE S2C

RESTORE THE ORIGINAL PREMIDCOURSE STATE VECTOR (S1) AND COMPUTE FIRST GUESSES FOR STEP 8 USING THE LATEST S2C:

$S2C - S' = \Delta\dot{X}, \Delta\dot{Y}, \Delta\dot{Z}$

$(S1 + \Delta\dot{X}, \Delta\dot{Y}, \Delta\dot{Z})_{POLAR\ FORM} - S1 = \Delta V, \Delta_{\gamma}, \Delta_{\psi}$

STEP 8

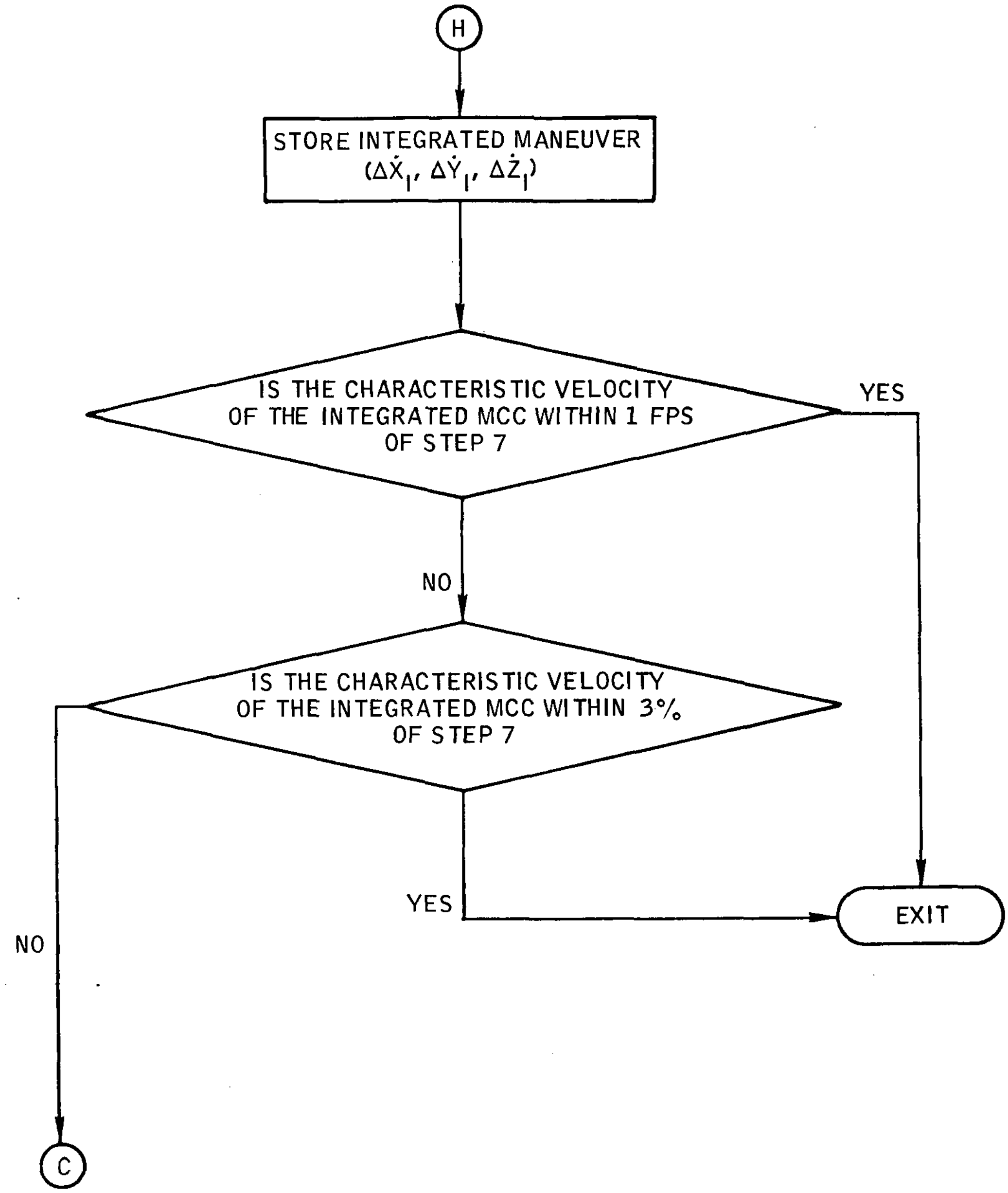
CONVERGE INTEGRATED FLYBY TO SPECIFIED INCL OF FREE RETURN AND OPTIMIZED HEIGHT USING STATE S1

INDEPENDENT VARIABLES	VALUE	STEP SIZE	WEIGHT
DELTA AZIMUTH MCC	COMPUTED	Ø 1 544	1
DELTA GAMMA MCC	COMPUTED	Ø 1 544	1
DELTA VELOCITY MCC	COMPUTED	Ø 1 524	1

DEPENDENT VARIABLES	MIN	MAX	WEIGHT	CLASS
HT OF PERILUNE	-.5 N. MI. OPT	+.5 N. MI. OPT	-	1
INCL OF FREE RETURN	-.01° (CONV VALUE OF STEP 7)	+.01°	-	1
INCL OF PERILUNE	90°	182°	1	0
HT OF REENTRY	64.0965 N. MI.	67.5665 N. MI.	-	1

H

FLOW CHART 3.- OPTIMIZED RCS FLYBY TO A DESIRED INCLINATION OF FREE RETURN (CONTINUED).



FLOW CHART 3.- OPTIMIZED RCS FLYBY TO A DESIRED INCLINATION OF FREE RETURN (CONCLUDED).

REFERENCE

1. Morrey, Bernard F.; McCaffety, Brody O.; and Morrey, Alfred E.: RTCC Requirements for Mission G: The Translunar Midcourse Correction Processor. MSC IN 68-FM-193, August 9, 1968.